

Curved Steel

How to Build a Machine to Bend Steel Beams

by David R. Whitney

Faced with the difficulty of bending steel beams into a curve, our limited steel shop has often relied on kerfing. By using a formula published in the article, “A Formula for Cutting Arcs and Circles” in the 1999 *Tech Expo Catalog*, we have been able to simplify and increase the accuracy of this process to a certain extent. However, when repetition is necessary, the margin of error is too great, and the process simply takes too long.

So I was excited when I saw a steel bender that appeared to have been fabricated in-shop at a United States Institute for Technology (USITT)-Southeast master class held in October 2004 at the Alabama Shakespeare Festival in Montgomery, AL. After talking to the technical director, Le Hook, and taking dozens of pictures, I returned home determined to build one for our shop at Radford University.

Starting at Square One

Since I had no drawings – just pictures – to work from, I knew I needed to research the physics behind the machine’s concept to understand the magnitude of the forces with which I would be dealing. I consulted a number of books on structural design and mechanics, including *Structural Design for the Stage* and the *Manual of Steel Construction: Allowable Stress Design*.

First, I investigated the amount of force necessary to bend the steel beyond its yield point, resulting in permanent deformation. The necessary force is dependent on a number of variables, including the type of steel, the shape of the beam and the distance between the points of force.

Then, I designed the machine so that the points of force could be set at different distances from the center roller, either 5½ inches or 9½ inches. The advantage of setting them close together is that you can achieve a tighter radius. Setting them farther apart allows you to bend larger beams.

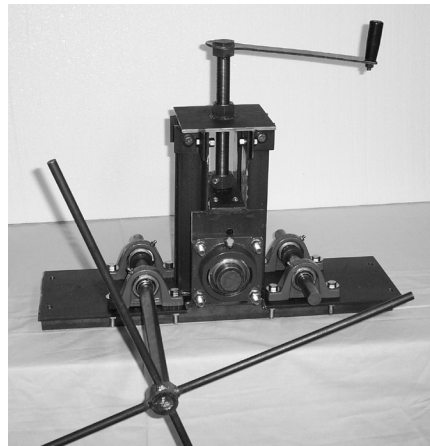
Using these distances and the formulas I derived from the books, I was able to calculate all the forces involved and check them against the manufacturer’s strength data for all of the parts I used.

Building the Machine

I scavenged steel from a local steel supplier, purchasing it at a discounted price. What I used works fine, but steel in other sizes could be substituted.

I followed the steps below in constructing the steel bender (*numbers in parentheses show position in drawing, next page*). I made all cuts with a horizontal band saw, unless otherwise stated.

- ✓ Weld together the base plate (17) and the supporting bar angles (18). Cut the notches out of both. I used an oxy-acetylene cutting torch to cut these notches.
- ✓ Drill holes for mounting the base-mount pillow blocks (15) in the base plate (17).
- ✓ Cut to length the ¼-inch flat bar pieces of the center roller carriage (9, 12, 13, 14). I cut them from ¼-inch x 8-inch flat bar, but a smaller width ¼-inch flat bar would be easier.
- ✓ Drill holes to mount the flange-mount pillow blocks (11) in the front and back pieces (12) of the

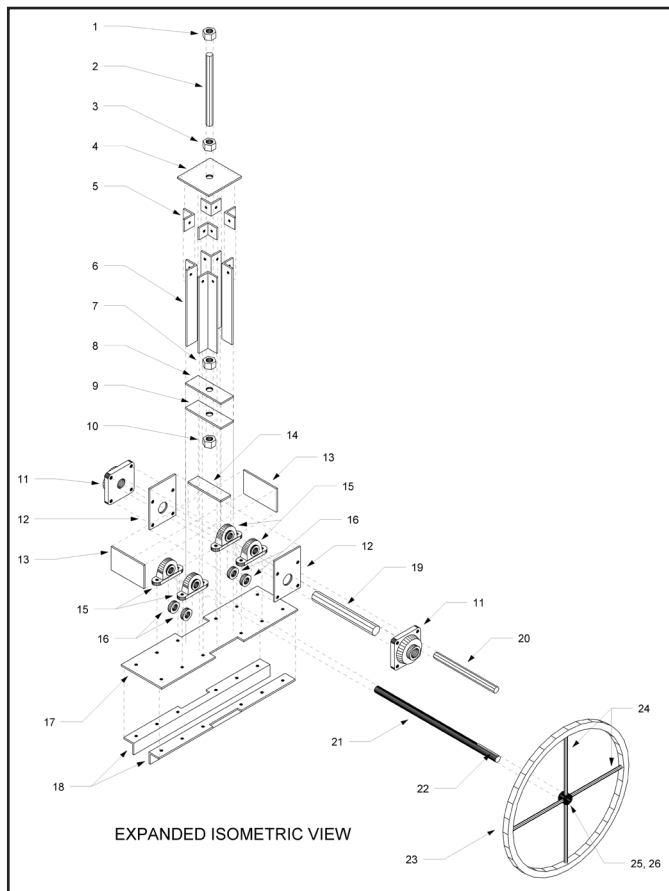


The finished steel bender is shown above. Your first project should be a wheel that you weld to the spokes.

SETC FIELD GUIDE SERIES

carriage. Cut 1¾-inch holes in the front and back pieces (12) and a 1½-inch hole in the top piece. I used bi-metal hole saws to cut both large holes.

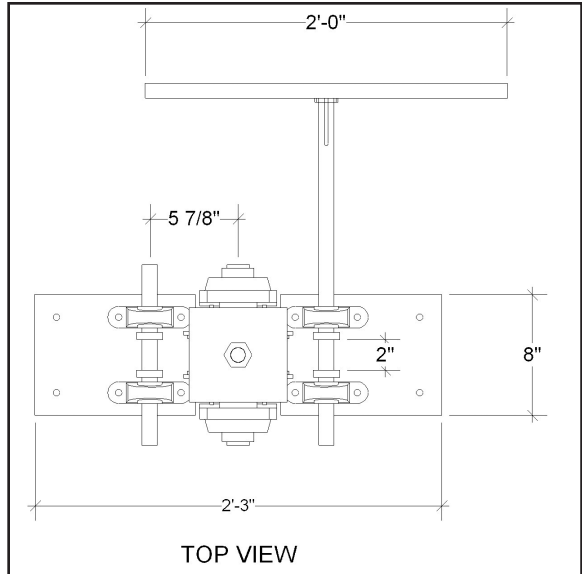
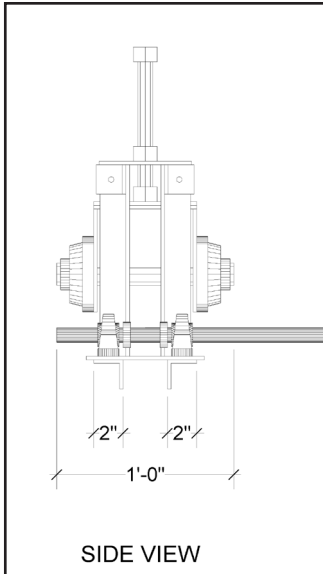
- ✓ Weld together the top (9), bottom (14), and side pieces (13) of the carriage.
- ✓ Cut the acme threaded rod (2) to length and insert into the hole in the top piece (9) of the carriage. Screw one of the acme threaded nuts (10) onto the rod (2) inside the carriage so that the rod's end is flush with the bottom of the nut. Weld the nut in place.
- ✓ Weld the front and back pieces (12) onto the rest of the carriage.
- ✓ Cut the vertical bar angles (6) to length and weld into place on the base plate (17) using the center carriage as a spacing guide.
- ✓ Drill a 1½-inch hole in a sheet of Ultra-High Molecular Weight (UHMW) polyethylene (8) and place over the rod on top of the top piece (9) of the carriage. Screw another acme nut (7) onto the rod (2) and weld to the rod just above the UHMW (8).
- ✓ Cut the bar angle tabs (5) to length and drill the ⅜-inch holes. Drill a 1-inch hole in the top plate (4) and place over the rod (2) on top of the vertical bar angles (6). Square the plate with the vertical bar angles, making sure the rod is perpendicular with the base plate (17) and the carriage.
- ✓ Weld the bar angle tabs (5) to the top plate, so that they keep the top plate aligned with the vertical bar angles (6). Drill holes through the tabs into the verticals. Bolt into place using the ⅜-inch grade 8 bolts.



Refer to the part numbers and the assembly diagram above in constructing your steel bender.

- ✓ Screw another acme nut (3) onto the threaded rod (2) and weld to the top plate (4), not to the rod.
- ✓ Screw the last acme nut (1) onto the threaded rod (2) and weld in place so that the rod's top is flush with the top of the nut.
- ✓ Bolt the flange-mount pillow blocks (11) to the front and back pieces (12) of the carriage with the ½-inch grade 5 bolts. Insert the 1½-inch steel rod.
- ✓ Bolt the base-mount pillow blocks (15) to the base plate (17) with the 7/16-inch grade 5 bolts.
- ✓ Cut the 1-inch steel rod to its two lengths (20, 21). I had the last four inches of the longer rod (21) keyed by a machine shop for future expansion so it could be powered by a motor (22).
- ✓ Cut the 1-inch and 1¼-inch pipe to create a small collar (25, 26), and weld to the end of the longer 1-inch rod (21). Cut the ½-inch round bar to length. Drill four

OUTSIDE THE BOX



holes perpendicular to the rod into the collar and weld the round bar into place.

✓ Insert the two 1-inch steel rods (20, 21) into their respective pillow blocks (15), making sure to add two shaft collars (16) in between the blocks on each rod.

✓ Grease the pillow and all surfaces that contact moving parts with white lithium grease.

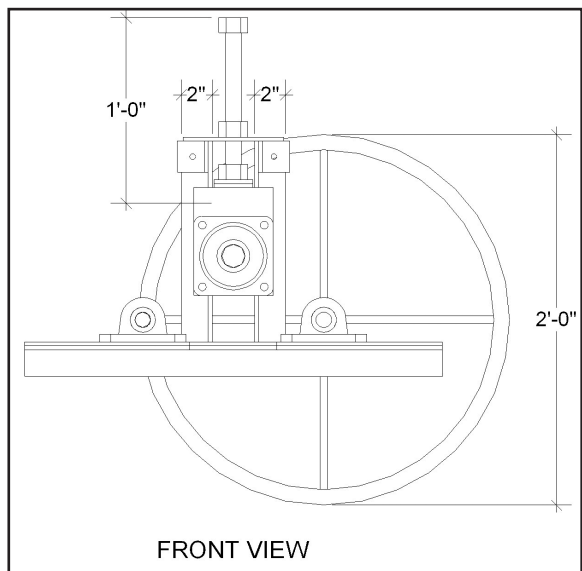
✓ The machine is now operational! As a first project, create the wheel by rolling two pieces of 1-inch x 1-inch square tube into semicircular arcs and welding together to form a circle (23). Weld to the round bar spokes (24).

Operating Your Steel Bender

To operate the machine, insert a beam through the center vertical supports so that it rests on the two side rollers and is below the center roller. Lower the center roller onto the beam by turning the threaded rod clockwise until a good amount of pressure is applied to the beam. Turn the wheel counterclockwise, which allows the center roller to apply equal force to the entire length of the beam as it passes through. When the end of the beam approaches the opposite side roller, reverse the turn of the wheel to return the beam to its original position. Turn the threaded rod again to apply more pressure, and repeat until the desired arc is achieved.

Use and Results

In theory, this machine can handle rectangular tube up to 3-inch x 1-inch x 11-gauge (along the short edge), square tube up to 2-inch x 2-inch x 1/4-inch, and flat bar up to 2-inch x 5/8-inch (along the



face). On smaller pieces, you should be able to achieve an outside diameter of 24 inches and possibly less. The thicker the beam, the larger the minimum diameter will be.

Although I designed most of the details of this machine and researched the mechanics and physics, the original idea, basic design and implementation came from others. Much thanks goes to Le Hook of the Alabama Shakespeare Festival, for none of this would have been possible had we not seen his steel bender and been able to ask questions about its use and construction.

Materials Needed

MATERIAL	SOURCE	COST
2 1½" Flange-mount bearings	McMaster-Carr/Grainger	\$109.38
1 1½" Steel rod (1-foot length)	McMaster-Carr/Grainger	\$ 16.82
4 1" Base-mount bearings	McMaster-Carr/Grainger	\$141.12
1 1" Steel rod (3-foot length)	McMaster-Carr/Grainger	\$ 18.90
4 1" Clamp-on shaft collar	McMaster-Carr/Grainger	\$ 13.44
1 1"-10 Steel acme threaded rod (3-foot length)	McMaster-Carr/Grainger	\$ 22.88
4 1"-10 Steel acme thread hex nut	McMaster-Carr/Grainger	\$ 18.56
1 12" x 12" x ¼" Sheet black Ultra-High Molecular Weight (UHMW) polyethylene	McMaster-Carr/Grainger	\$ 8.40
1 1½" x 1½" x ¾" x 8' Bar angle	Steel supplier	\$ 15.00
1 1½" x 1½" x ¼" x 8' Bar angle	Steel supplier	\$ 12.00
1 ¼" x 8" x 5' Flat bar	Steel supplier	\$ 30.00
Miscellaneous steel	Stock	\$ 0.00
Nuts, bolts and washers (Grade 5)	Hardware store	\$ 35.00

More Drawings

To view more construction drawings for this project, visit the website:
<http://portfolio.drwhitney.net>.



**Total Cost:
Under \$450**

David R. Whitney, who was a student at Radford University when he wrote this story, now is a technical director at Creative Visions, Inc., in Raleigh, NC. If you have questions about this technique, e-mail him at david@drwhitney.net.